SEILAF: TACTIC OPTIMIZATION[1]

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Abstract

SEILAF is a system designed for training, simulation and research in the fight again forest fires in a 3D world of a great virtual realism. A consortium of technological centers CITIC and CATEC, enterprises such as INDRA and FASSA, and the University of Cordoba have taken part in the design. The simulation center is located in Aeropolis, near the airport of Seville in Andalusia, Spain.

The system is comprised by three interconnected simulators: a flight simulator of a 412 Bell helicopter, a flight simulator of a fixed wing aircraft to coordinate the tasks of the aerial coordinator and a launching command outpost simulator where the forest fire extinction technical direction team can be trained, all this in a relevant realistic scenery of high resolution. This idea is totally original. It will be the first time that a spreading fire server with the modeled action of extinction resources is included in a tactical environment.

Since the first fits and tests of the system we have been able to analyze and model hypotheses in the development of exercises, responding what resource management in a regime of determined fires is the most efficient and safe tactic of fire extinction.

Key words: virtual training, SEILAF, fire and smoke simulation.

Introduction

Response organizations to forest fire, in similarity to people (Maslow Pyramid), as meeting basic needs evolve into structures of more complex, efficient, intelligent and adaptable functioning to various socioeconomic contexts and fire regimes.

At the base of our pyramid there would be a basic organization and a minimum resource level, on a step above a standardized and certified formation, above a system of total security, above this a high reliability organization (HRO) and at the top there

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would be the optimization of the knowledge management whose global indicator could be the maximum efficiency.

Moreover, the eternal search for the ultimate solution to the problem of emergency management that wildfires often cause also goes through several stages though this one in a little sequential way, as may be, the discovery of the miracle remedy, the final invention, the panacea of new technologies, to return to basic and robust extinction actions.

The studied organizations could be grouped in two distinct generic types and differentiated from strategic models of management of forest fires extinction:

1. Those of direct attack. Their main tendency is always to minimize the area affected by the fire directly attacking the advancing fronts.
2. Those of indirect attack. Their main tendency is always to contain the fire in a close perimeter established by means of already existent defense lines or to be built.

Both models, however, share the same common objective, namely, the extinction of the fire at the lowest and economical costs, minimizing all kind of direct and collateral effects,

Both trends need guidelines to enable them to size their resources always seeking the desired equilibrium point, although some issues will go on existing such as the appropriate initial dispatch of resources with the optimum level of resources. In economical booms we have extinguished some fires by flood. In contrast, in times of scarcity, inadequate level of resources along with a dispatch mediated by the phrase "wait and see" cause the effect you want to avoid, the exorbitant level of expenses to attend fires causing immeasurable losses.

Resource dispatches have always been considered as the initial Plan of Action whose strategies and adopted tactics greatly differ from the experience, training and administrative position of the person in charge. In Spain, according to the Autonomous Community and within this by province or region differences are remarkable. Some are based on the inconsistent fire regime but others just rely on a more or less knowledge management. This variation is what we want to validate and verify in SEILAF. And of all the answers be able to choose the most effective according to a typology context.

Our research efforts have initially been for tactical movements. As example, assume that by default the best and undoubted is always to concentrate first all the efforts and resources in stopping the front fire. Then trials have been raised to see if this tactic can be validated with the optimal efficiency.

As a note, SEILAF, as well as any other fire simulator cannot be "the true machine" (sic.) Rodriguez and Silva, F. Instead, the ability to acquire knowledge that the system has allows certainly discovering and validating the modeled responses whose great advantages are economy of resource, risks and time.

Objectives:

We can determine the scope of the present communication on three main objectives:

- To publicize the SEILAF system by exposing research hypothesis and the first trials.
- To share our initiation into tactical knowledge management of virtual extinction maneuvers.
- To open new ways of study and research using SEILAF as a laboratory of experimentation and collaboration.

Methodology

Hypotheses

There are several postulates or hypotheses. Three have been chosen for their significance and importance to consolidate a common methodology to facilitate further testing and validation studies.

A- Initial attacks always to the head of a fire.

B- To cover an area or what are the consequences if another fire starts having the committed response

C- Minimum range of response

Components of the system

The system architecture is composed of six main elements.

Server room—

It is where the brain of the system resides. It has 9 L-shaped racks, full of COTS equipment that guarantees the maximum performance and control of each element of the system as well as a quick replacement in case of failure.

The system that coordinates all others is called HOST and its functionality is:

- Ensure real-time simulation.
- Manage the various commands, modes and phases
- Synchronize with all the systems that make up the simulators
- Execute and perform proper cycling simulation models

The three simulators are based on the same HW and SW and the main difference is the number of elements of each system. This favors the robustness of the system and dramatically reduces the response time to a contingency.

Figure 1—Equipment room

Bell 412 Helicopter simulator—

It consists of a Bell 412 helicopter cabin, equipped totally surrounded by a spherical dome of 3.25 m radius with a 6 projector system on a base that is supported by a hydraulic movement.

The simulator is designed to meet the requirements established by the standard JAR-FTD level 3A.

Figure 2—B412 helicopter simulator

ACP simulator (Advanced Command Post) —

The adopted solution is a vehicle with all simulated communication systems and a weather station in front of a display where two eight-meter high resolution projectors display the virtual scenario where the exercises are carried out.

Figure 3—Advanced Command Post (ACP) Simulator

COA Simulator (Certificate of Authorization) —

In a cabin of a KingAir airplane two monitors have been arranged in series of instrumentation of utility in air coordination. In this case a rear projection system was used which covers the entire field of vision necessary to achieve an improved immersion in the coordination and management of air operations.

Figure 4—Air Coordinator (COA) Simulator

Instructor Posts—

In the case of COA and ACP the instructor posts are not shipped. Each instruction post consists of a communication system and three monitors with the following tools:

- IOS (Instructor Operation System). Interface that the instructor uses both to plan and to execute exercises.
    - In execution mode the following actions can be enhanced.
        - To stop, load and execute an exercise previously defined in the planner (LPSG)
        - To modify the initial conditions
        - To control simulation (execution, pause, stop)
        - To follow the state of the system and messages of the instructor
        - Monitoring and control:
            • Flight position and parameters
            • Communications
            • Failures
            • Tactical entities
            • Environmental and visual conditions
            • Fire Propagation
            • Sessions and brands (Debriefing)
    - In planning mode the instructor can perform the following operations:
        □ Stop, create, delete and modify exercises
        □ Starting Position
        □ Initial load
        □ Preset failures (time, event, condition)
        □ Environmental and visual conditions
        □ Fire
        □ Tactical environment
        □ Edit maneuvers
- There is no distinction of type of simulator. The created exercises can be run in any of the three simulators
            □ Maintenance of libraries
            □ Radioaid database
            □ Model database (ET)
            □ Users
            □ Way points & routes
            □ Areas of interest (water points, lakes, etc.)

□ Data packages (environmental, visual, position, failures, radio aids

Debriefing station—
Recording system where the evolution of the missions, voice communications and camera images loaded in each simulator are recorded. The system has a storage capacity of up to 500 hours online simulation.

Tactical environment

The tactical environment is the system responsible for:

- simulating the participant entities in the scenario
- informing the rest of the subsystems the state of the entities
    - Instructor post
    - Host
    - Visual
    - Fire environment
    - sounds

The actions of each tactical element have been modeled according to their actual behavior in an automatic logic, being configurable their action perform under certain parameters, for example, when making a line of defense or in their extinguishing capacity in direct attack or in more basic parameters as their displacement speed.

Fire and local wind server

Developed by the University of Cordoba and CATEC, respectively, SEILAF has a server of fire and of local wind, specific to simulate propagation conditions in any ignition source that under given weather conditions could be established anywhere of a chosen geo-specific scenario.

A major feature of this server is that works in real-time based on the "Visual-Cardin" theoretical model of propagation. Thus due to the fit of the model we can visually see sizes, colors and shapes of flame and smoke with a physical sense of the dynamics of fire behavior. As great value added it has an answer to all actions taken by any tactical element in its task of extinction, even in conducting widening burns and technical fire.

The reality of the dynamics of spread of fire in forest ecosystems shows that under certain conditions and depending on the humidity of the live vegetation located in the canopy, as well as the vertical transmission of the convective effect from the surface displacement fire, processes can be generated which at high linear intensities of advancing fire, individualized kinking phenomena of trees can be generated, causing passive or intermittent fire advancing through the crowns. This reality has been included in the mechanisms of fire progression, as well as the definition of areas potentially capable of generating ignition of new outbreaks of fire, depending on the occurrence of upward thermal energy, wind speed at height, type of fuel model and the fuel probabilistic state off the ignition. The origin of the sparks always has a prime position in the front of the fire and height taken up when the convection column moves from its vertical development to be moved by the head wind.

The output parameter of flame intensity (kW/m) has been used to differentiate areas of head or engine fire and geo-locate in said cells the base of convection columns. Torching and the step to crown fire are established according to the equations of critical intensity of tree crown (for torching) and burned crown fraction (to determine if the crown fire is passive or active).

Database

The large visual database is shared by the three simulators. In joint exercises from each position it has its specific vision. It is started from 15 detail scenarios of 20x20 km where different types of fires have tried to be incorporated; orographical, wind and convective fires, in diverse landscapes and conditions ranging from natural forest areas as Muniellos in Asturias to humanized landscapes and even extremes of forest-urban interface as Massanet in Girona.

The geo-specific SEILAF database consists of:

- The database comprises the Iberian Peninsula, Balearic Islands and Canary Islands.
    - Based on DTED2 and from Landsat satellite image of 15-meters resolution for the terrain in general
- Based on mdt and high detail resolution orthophotos or geo-specific scenarios
- Airports
- CEDEFOS/Bases of Air Resources
- Points of water of various types/and load difficulties
- Specific models:
    - Air elements
    - Ground tactical elements

The high detail scenarios have been performed on the restitution of 20km x 20km of each high detail area; the 3D elements to model required for training were determined:

    - Barriers
    - Checkpoints
    - Wind elements
    - antennas, repeaters
    - Power lines
    - Meeting points (flat area with heliport signal)
    - Buildings with heliport, etc.

  - Trajectory files have been generated (starting from 1:50,000 vector data) of roads and highways that are considered necessary for the movement of ground tactical elements.
  - Forest areas have also been modeled based on the 1:50,000 vector data and data from the national forest map to determine the type of species to settle in each case.
  - On forest areas 3D models of trees were added with a prefixed and randomly density (with the species obtained from the forest map)
  - The different densities of forests have been taken into account from that observed in the orthophoto.
- Diversity of specific models or avatars of air elements with different camouflages and matriculates:
  - CL-415
  - AT 802
  - AT 802 FB
  - PZL DROMADER
  - CESSNA 337
  - B407
  - B412
  - A119KOALA
  - AS350B3AS355N
  - BO 105
  - SUPERPUMA
  - SOKOL PZL SWIDNIK W3
  - KAMOV K-32
  - SIKORSKY S70 FIREHAWK
  - M18 TV
- Specific models or avatars of Terrestrial Tactical Elements with a configuration tool of identification code:
  - Lightweight pump
  - Heavyweight pump

- Nurse pump
- Dozer on chains
- Helicopter crew transport
- Ground crews type II
- Units type III
- Firefighters
- UME

Image generator

For the interaction between fire and visual interface protocols and interfaces of appropriate communications to communicate the fire server and other systems involved have been defined.

Initialization of fire—

Information on materials (fuel types and terrain) of the area chosen for the simulation is provided for the fire server and this area is reflected on a grid of cells of a size indicated by the user interface, always within some values and on an area of orography previously known and studied.

This grid will not be visible in simulation time, but will be available as Debug tool that helps us to verify the consistency of the data sent by the fire server and those that are represented visually.

Figure 5—Cell grid View

Particle system—
Columns of smoke are particle of systems with certain properties, characterized by different "affectors" which determine the type of smoke to represent.

Change of the vegetation status-
Models of vegetation will change to a "burned" status according to the advance of the fire. Therefore all trees within the fire area have been assigned previously to the cell occupied on the ground, so when changing this, trees in it change too. For this, it has been necessary to rearrange the trees in memory and restructure the way in which they were accessed to optimize individual change from one tree model to another.

Definition of extinguishing agents—
After consulting with experts, several types of agents have been defined, with their properties and behavior of the affected areas of land, establishing three types of agents: water, ammonium retardant and foam.

Download of extinguishing agents from air tactical entities—
One of the leading steps against wildfires and object of training will be the air downloads of extinguishing agents. This will affect the fire area interacting with the flames obtaining the right result for each cell. This action will be reflected in the visual interface with a download effect that varies depending on the type of agent used. The water discharge is another effect made from particle systems, and the same fitting criteria are applied for the fire and smoke.

Evolution of the fire—
The evolution of the fire is reflected with, in addition to the effects of fire and smoke, a burning field effect, in charcoal and burnt, using a technique of painting on the Framebuffer Object and projecting the state of each cell on the grid defined.

Action of the ground tactical entities—
Similarly to air entities, land vehicles perform downloads on terrain areas affected. The action of the brigades, a type of land tactical entity is reflected in the form of ditches on the land affected, the so-called defense lines, or in direct attack with a “batefuegos” –a fire bating device-, working as a spearhead and even they made firebreaks. To reflect the effect on the visual interface with the user the same technique to burn the ground is used.

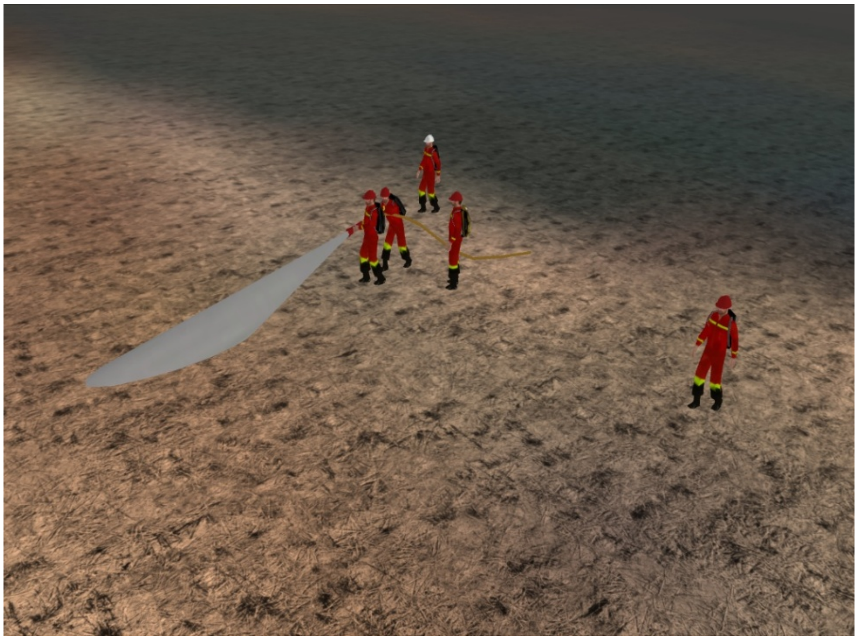

Figure 6—Example of figurative action of extinction

TRIALS

Exercises performed so far are not representative either in number or in optimal system state but are significant as to variety of the organizational system of origin and they are guiding in determining or focalizing factors of tactical improvement.

Hypothesis A— Initial attacks always at the front. The designed exercise has been repeated 4 times.
Scenario: Sierra de la Culebra, Zamora, Castilla y León.
Day: July 15, 2003.
Weather conditions: T 42 ºC, Rh 18%, 20 days last rainfall, HCFM 3%, HAINES 4
Ignition start time: 16:15 GTM
Starting area: 5000 m^2
Location: 41º 55'40, 20" N; 6° 49' 31, 60" W
Level of resources: 1
Exercise duration: 63 minutes
Variable: Wind direction

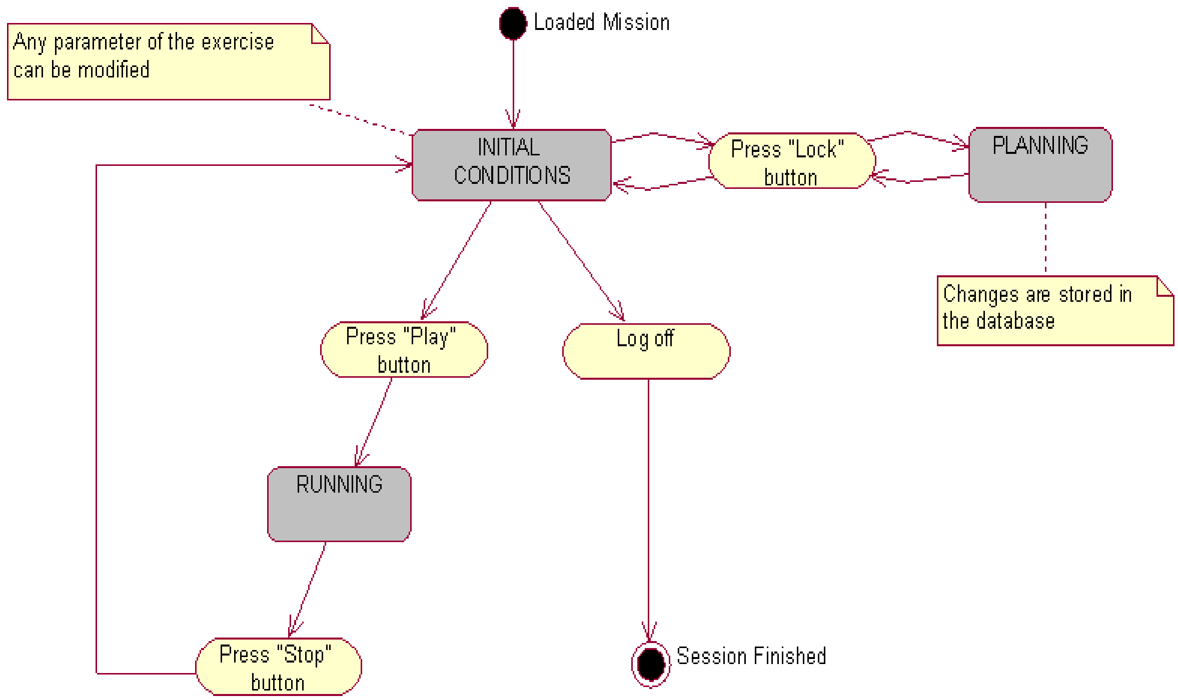

Figure 7—Flow chart of operation exercises

Hypothesis B— The myth of covering area

Scenario: Ibias, Asturias.

Day: July 15, 2013

Weather conditions: T 27 ºC, Rh 14%, 12 days last rainfall, HCFM 9%, HAINES 3

Ignition start time: 20:30 GTM

Starting area: 3000 m^2

Location: 43º 02'29, 35" N; 6° 19' 31, 60" W

Level of resources: 3

Location: IBIAS

Exercise duration: 87 minutes

Variable: Number of aircrafts on base

Hypothesis C— Minimum range of response

Scenario: Villaviciosa, Córdoba, Andalucía.

Day; July 15, 2013

Weather conditions: T 39 ºC, Rh 8%, 40 days last rainfall, HCFM 1%, HAINES 4

Ignition start time: 16:12 GMT

Starting area: 1000 m^2

Location: 38º 6´ 14,39" N; 5º 0´35,75" W

Level of resources: 2

Location: Northwestern impoundment

Exercise duration: 32 minutes
Variable: Delay in dispatch

Results (Discussion)

Hypothesis A— Initial attacks always on the head of a fire. This tactical premise is only efficient provided the extinguishing capability exceeds the intensity of the main front.

Other conditions were discovered. To stop the head is an advantage because it minimizes the area/perimeter and with only one resource fires can be controlled, whenever any side may have a greater potential danger. Constant conditions and control times not exceeding half an hour. The classic tactic and safe, from head to tail by the easiest flank to extinguish and anchor, has yielded very efficient results, as propagation conditions were changed or expected means passed to inoperative status.

Hypothesis B— The myth of cover area
The exercises have been developed in the IBIAS scenario due to the fact that a fire regime is typical with days of many simultaneous fires.
The created sequence of fires has been up to five simultaneous fires with an output of air resources of a BRIF (Tineo) comprising two Sokol, a Kamov (Ibias) as a high capacity bomber helicopter and a B3 aircraft with a heli-transported crew type 1.

The trials have focused on validating the tactical scheme of mass extinction as more optimal than done in parallel. The concentration of resources that can extinguish the fire as quickly as possible is always best until now where priority in value or in the danger of a new incipient fire triggers the urge to move all means to that new focus.

As a possible conclusion to be validated one can say that the best place to go for concurrency situations where resources can be is acting.

Hypothesis C— Minimum range of response.
The times between ignition, dispatch and arrival of the first mean are critical, and these can only be attenuated by an initial dispatch compensated and adapted to circumstances of risk and evolution of fire. If this opportunity is obviated the stepped dispatch did not usually resolve the situation of fire break always needing an extended attack strategy.

The battery of exercises conducted so far has been to prove how a ten-minute delay in the departure of the BRICA of the CEDEFO of Cabeza aguda may be offset by the dispatch of a KAMOV helicopter from the location of Villar de Buey and what would happen if we increase the delay in the arrival of this reinforcement until checking out for which assumptions it would be in a borderline situation of reinforcement.

Conclusions

Tactical optimization strategies drawn from each of the hypotheses have been unified and classified into four sections.

Improvement of security

The various exercises have shown that a wrong initial decision making is what makes a very high percentage of concatenation of events until the disaster. Thus one of the first conclusions is the need to increase the initial assessment capabilities to optimize the first reactions without loss of opportunity. The exercises behaved like a chess game in which each movement from the opening causes endless possibilities and where false steps unbalance the game.

Therefore we see hard to bet by the concept of "the safest tactic" since to small changes of factors ranges of variability are exponential. On the other hand, the current procedures could be standardized and revised to adequate them to the most intense fire behavior and to the increase extinction capacities. The ineffective tactics are accompanied by the free risk-taking, in danger and goal achievement. So it becomes very important to have a strategic vision and a clear and evaluated intent in the planning of all actions.

Improvement of performance

The main causes of loss of detected efficiency can be summarized into three; inadequate dispatches, inoperativeness of tactical entities and widening gap in the transmission of orders of the Action Plan.

Optimization of economic efficiency

The conclusion is that the contribution from tactical optimization to economic efficiency is negligible compared with other external or far away factors such as preventive actions or land management.

What is valued as essence is to know extinguishing capabilities in relation to fire behavior to avoid unnecessary effort.

Response before unexpected

In the still few occasions where small contingencies have been introduced in the development of the exercises it has been proven that they do not disturb when actions are taking place with short-term planning. But when these are structured and they reach greater temporal horizons the reaction capacity resents having a strong inertia to change strategies. In the only case exercised where there was a Plan B, the result was much more effective. The experience/training factor we assume will be crucial to deal with these types of situations. The test plan will continue shortly.

Finally, to conclude SEILAF as environment of study has proved to be capable of responding to the simulation of multiple variables and cases that wanted to be analyzed. The tools available in the IOS have allowed proper planning for each trial as well as the follow-up in their execution and recording of all exercises. The immensity of data generated makes to raise the need to start having ad hoc analysis tools to achieve transform information created in knowledge.

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